AGRICULTURAL EXPERIMENT STATION

KANSAS STATE AGRICULTURAL COLLEGE
MANHATTAN, KANSAS

POTATO DISEASE CONTROL IN KANSAS

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SUMMARY.

The more important diseases affecting the potato tubers in Kansas are: Rhizoctonia, blackleg, wilt (tuber infection), and scab. Tip burn, or hopper burn, and early blight are the only foliage diseases of importance. The annual loss from these diseases varies approximately from 15 to 30 per cent of the crop during different seasons.

The corrosive sublimate treatment is recommended for the control of Rhizoctonia, blackleg and scab. Greatly increased yields have been obtained from seed treatment. It is an operation which no potato grower can afford to omit. Experiments are in progress at this station to determine the value of the hot formaldehyde treatment. Additional data are necessary, however, before its real value can be determined. The cold formaldehyde treatment is not recommended for potato diseases.

Experimental results extending over five seasons, from spraying the potato crop with Bordeaux mixture, show that this practice must be looked upon as an insurance against the possible loss through epidemics of foliage diseases. Large increases in yield do not seem probable as a result of the application of a fungicide except during seasons of serious epidemics of early blight, hopper burn or tip burn. If sprays are applied, the 4-5-50 or 4-8-50 Bordeaux mixture should be used rather than the weaker formulas.

Considering the results obtained from spraying with Bordeaux mixture for the period 1918-1923, it would seem that the returns have been too small to warrant the cost. It should be remembered that the spraying experiments cover only a five-year period and that seasons and conditions might occur when different results would be obtained.

The use of copper dusts for the control of foliage diseases has not been tried over a sufficiently long period to warrant a definite statement regarding their value. Arsenical dusts for the control of the potato beetle are successfully used in Kansas.

Certified seed of good yielding strains of potatoes has distinct merit. It outyields the average commercial seed. Certified seed should carry less infection of diseases.

Growers are advised to pay considerable attention to the yielding capacity of the seed they buy. The appearance of the seed will not tell all that should be known concerning it. Various states are producing seed potatoes adapted to Kansas conditions.

The potato yields in this state have been materially increased when seed treatment, good yielding strains of seed, and the use of barnyard manure and green manure crops have been employed.

Potatoes are being grown under irrigation in the Dodge City and Garden City districts with promising results. Care should be taken to keep these new soils from becoming infested with troublesome potato diseases.

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POTATO DISEASE CONTROL IN KANSAS.[1]

E. A. Stokdyk[2] and L. E. Melchers.

INTRODUCTION.

The commercial production of potatoes is confined to a very limited area in Kansas. It follows the Kaw and Arkansas river valleys very closely. Until recently it was restricted to the eastern part of the state along the Kaw valley, Pottawatomie and Riley counties forming the western border. This is due to the distribution of rainfall in Kansas, which decreases from east to west. New districts, however, are being developed along the Arkansas river valley in the vicinity of Dodge City and Garden City, where commercial production is successful under irrigation.

The limited area of the Kaw valley which is suitable for potato production makes this land very valuable. The crop in 1919 from 10,700 acres was valued at $1,690,000, while the value of the crop in 1920 from 10,800 acres was $2,287,000. This has resulted in continuous potato production without rotation, except following the crop, which is dug early in July with a green manure crop. Such a system undoubtedly is favorable for the propagation of plant diseases. Data taken from the State Board of Agriculture reports on the seven leading potato counties in the Kaw valley show that in the period 1914-1916 there was an average yearly acreage of 11,870 acres, with an average yield of 97.9 bushels per acre, while in the period 1917-1919 there was an average yearly acreage of 11,188 acres, with an average yield of 88.4 bushels per acre.

The fact that various plant diseases were largely responsible for the decreased yields was commonly accepted by the growers. Weather conditions no doubt are important, but the growers felt that other factors were responsible for the decrease in yields. Their interest in the experiments and demonstrations conducted to prevent losses by plant diseases is shown by the increase in acreage planted to treated seed in the various counties in the last four years.

Acknowledgment.—The authors are specially indebted to the following people for their aid and coöperation in conducting these studies: Messrs. M. T. Kelsey and G. E. Kelsey, Topeka, Kan., on whose farms many of these investigations were conducted. Frank O. Blecha, county agricultural agent, who aided in all the experiments in Shawnee county. Messrs. John W. Blachly, formerly extension plant pathologist, and Prof. H. H. Haymaker of the Department of Botany and Plant Pathology of the Kansas State Agricultural College, who gave assistance in the beginning of these investigations. The authors likewise appreciate the kindness and coöperation on the part of all the potato growers on whose farms investigational work was conducted during the period 1918-1923.

1. Contribution No. 218 from the Department of Botany and Plant Pathology.
2. The senior author is extension plant pathologist, Kansas State Agricultural College.

LOSSES FROM POTATO DISEASES IN KANSAS.

The annual loss from potato diseases in Kansas aggregates many thousands of dollars. Since the yearly prices for this crop fluctuate, it is perhaps more advisable to estimate some of these losses in bushels. The most important diseases which occur in this state are given. A conservative estimate of the losses from these diseases for the last six years is given in Table I.

TABLE I.—Estimated annual losses in the Kansas potato crop due to diseases, 1918 to 1923.

ANNUAL YIELD IN BUSHELS	Year	Per cent of loss from diseases					Loss in bushels (a)
		Rhizoctonia	Blackleg	Scab	Tipburn and early blight	Total	
2,652,004	1918	5	½	¼	10	15¾	495,775
3,945,451	1919	8	8	trace	20	36	2,219,316
4,033,046	1920	8	5	trace	8	21	1,072,075
4,078,878	1921	20	5	½	10	35½	2,244,964
4,767,469	1922	15	5	trace	10	30	2,043,201
4,918,000	1923	12½	3	½	2	18	1,079,560

(a) These estimates have been made by assuming that the annual yield represents the differences between 100 per cent and the per cent of loss from diseases. For example, in 1922, 4,767,469 bushels equals 70 per cent of what the yield might have been if 30 per cent loss had not occurred.

Since the annual losses for these years vary from 15¾ to 36 per cent, it is quite evident that if methods can be used to overcome 75 per cent of this loss, a big saving would result. It should be remembered that some of the important factors producing this annual loss are: (1) The amount of infection which is carried on the seed. Some years it is much more abundant than others. (2) The soil temperature and moisture conditions at planting time and during the early stages of growth of the potato plant. A cool, wet spring is most favorable for the development of and injury from Rhizoctonia and blackleg. (3) The type of soil in which the potato crop is grown. A heavy soil does not warm up as rapidly nor is it as well drained as a sandy soil, consequently diseases are worse on the heavier soils. (4) Hot, dry spells in June and July seem favorable for an increased amount of tip or hopper burn. (5) Prolonged rainy spells in June favor the development of early blight. Climatic conditions in themselves are not the cause of plant diseases, but they make the environment favorable or unfavorable for the organisms causing the disease to develop and spread.

Practically all of the seed which is used in Kansas is secured from northern states. This necessarily involves the matter of bringing in plant diseases with seed shipments. Even though many of the seed-borne diseases can be satisfactorily controlled by seed treatment, there is always the constant danger of soil infestation with some of these diseases. This is especially important because good potato land is limited. Some of these diseases can accumulate in the soil to the extent where noticeable injury will result even if such land is planted to treated seed. It should be remembered that generally not enough consideration is given to rotation, and the growing of legumes or some other green manure crop. Plowing under green organic matter or manure is essential, since it will help to make conditions most favorable for the growth of the potato plant and at the same time make them less favorable for the spread of such diseases as Rhizoctonia and blackleg.

POTATO DISEASES IN KANSAS.

Rhizoctonia (black scurf), blackleg, scab, dry rot and wilt are among the most important diseases which are brought into the state through the seed. All but scab and dry rot attack the stems of the potato plant. Stem infection causes severe injury, since it results in partial or entire loss of the potato plant.

Early blight and tip burn (including hopper burn) are the only foliage diseases which are of importance to the Kansas potato grower. Any injury to the foliage of the plants will affect the yield. Experimental work on the control of these diseases has been conducted and the results to date indicate that certain sprays are more effective than others. Timely applications of fungicides to the growing plant are a means of protecting the foliage from injury resulting from tip burn and early blight. It is evident that anything that will retain or prolong the normal vigor of the foliage would help to increase the yield.

RHIZOCTONIA (BLACK SCURF).

Symptoms on the Tubers.

The fungus which causes this disease is carried on the outside of the skin of the potato tuber. Small black masses or lumps from the size of a pinhead to that of a small pea can be seen adhering to the skin. These lumps look like soil. Tubers carrying this infection, if washed in water, will readily display the black fungous masses, since they do not wash off. Potato growers frequently speak of Rhizoctonia as "the dirt that won't wash off." (Fig. 1.)

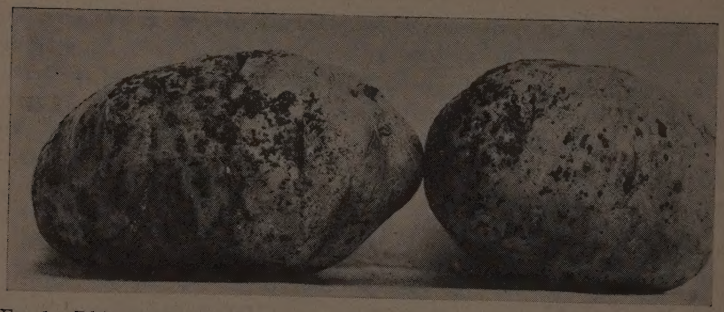

FIG. 1.—Rhizoctonia sclerotia on potato tubers—"The dirt that won't wash off."

FIG. 2.—Rhizoctonia lesions on young potato plants. Note lesions and places where sprouts have rotted off.

Field Symptoms on the Stems.

1. Spindly sprouts show in some cases that they are secondary growth. The original sprouts rotted off.

2. Distinct brown or black, sunken areas from one-eighth to one inch in length occur on the sprouts.

3. Infected areas frequently girdle the sprout. This stage just precedes the complete rotting off of the stem. (Fig. 2.) Missing hills are the result of this disease. (Figs. 3 and 4.)

4. The infections on the stalks do not cause a slimy rot, but more of a dry rot.

5. Diseased stems are always short, spindly, and frequently yellowish.

6. If affected plants form tubers they are frequently small, misshapen, and unmarketable. Sometimes the small stem attachment connecting the tuber with the stem is attacked and rotted off.

7. Occasionally small aërial tubers are formed in the leaf axils on the potato stems above the ground. This is not common in the Kaw valley district, but does occur in the irrigated regions.

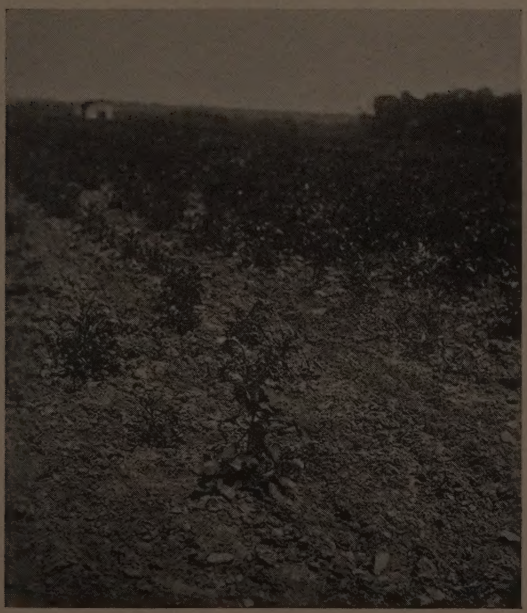

FIG. 3.—A poor stand of potatoes; the result of ravages of Rhizoctonia.

Life History.

When affected seed is planted without treatment, the black fungous masses on the tubers become active and infect the young sprouts. Cool, wet weather, when it extends over long periods, is especially favorable for the development of the fungus. There are indications that the *Rhizoctonia* fungus can live over to some extent in the soils in this state; therefore all precautions should be exercised to keep the soil in the best condition by rotation and growing

FIG. 4.—The results from seed-potato treatment in Sumner county, 1923. Left, untreated; right, treated.

legumes or other green manure crops. Observations to date indicate, however, that the *Rhizoctonia* fungus is not very prevalent in the potato soils, which is evidenced by the lack of development of the black specks or lumps on the potato tubers at digging time. It can, however, live over in the soil. This is shown by stem lesions on volunteer plants late in the season. The injury from this source of infection is insignificant as compared to the chief injury which results from planting untreated, affected tubers.

Control Measures.

Avoid buying seed that has large amounts of Rhizoctonia. Give all seed the corrosive sublimate treatment before cutting.

BLACKLEG.

Symptoms on the Tubers.

The tubers usually decay from the stem end inward. Canals or rotted pits occur, which are filled with a slimy bacterial ooze. (Fig. 5.) This disease in some cases has been responsible for the soft or watery decay which takes place when potatoes are shipped in July and August.

FIG. 5.—Late infection of blackleg in tubers.

Symptoms on Young Plants.

Blackleg infection on young plants is sometimes confused with Rhizoctonia. These diseases can be readily distinguished:

1. Blackleg causes a distinct black, soft or slimy rotting of young plants.
2. The decay extends from the seed piece to the surface of the ground, turning the entire underground part of the stem to a coal-black color. (Fig. 6.)
3. The leaves of the plant turn pale yellow, roll or curl, and finally the plant wilts.
4. Both young and old plants are attacked. Stems of older plants become more or less hollow. In wet weather the stems become limp and slippery.
5. Diseased plants pull out of the soil very easily.

FIG. 6.—Blackleg of potatoes, showing blackened condition of the stems.

Life History.

The bacteria which cause this disease are carried to the field by the seed. Bruised tubers are perhaps responsible for carrying this disease. Affected seed pieces decay in the ground and transmit the infection to the sprouts. This finally results in a missing hill. Under conditions favorable for the disease the young plant is killed during the first four weeks of growth. Late infection may occur in the Kansas crop and cause considerable damage at digging time. The disease is worse during wet seasons, and has been found to

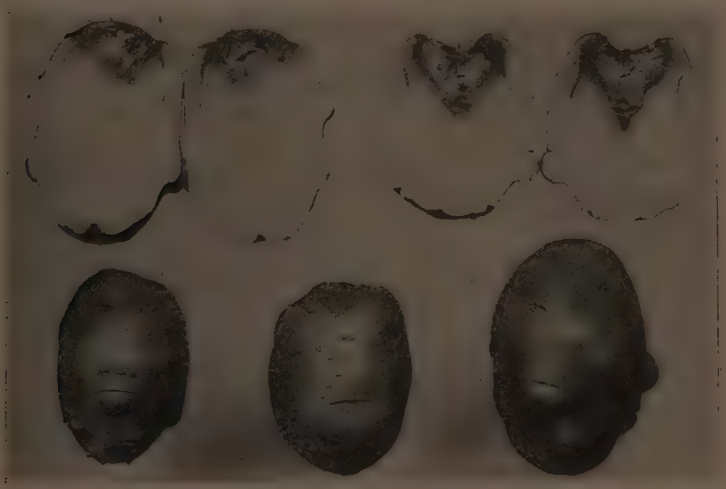

FIG. 7.—Dry rot and wilt infection showing a shrinking at the stem end.

spread in the field. Slightly infected plants do not die, but produce tubers which become infected and transmit the disease. A slight infection in the potato tuber may cause decay in transit, especially if the potatoes have been exposed to sun injury and rains.

Control Measures.

It is not known to what degree the bacterial germs which cause this disease can live over in the potato soils of Kansas. Crop rotation helps to overcome dangers from this source. Seed that is sound and which does not show decay on the outside or inside of the tuber should be planted. Disinfect all seed before cutting; this will kill the germs that may be on the outside of the potato. Use the corrosive sublimate treatment.

FUSARIUM WILT.

Symptoms in the Tuber.

This disease may be recognized in the tuber upon cutting a slice from the butt or stem end. Infection is shown by a browning of the vascular ring (water and food channels), which may be traced only a short distance into the tuber (Fig. 7). This infection was carried from the diseased stem of the potato vine to which the tuber was attached. The tubers do not always show infection at the time of digging, but if they are kept over summer the discoloring is very common. In storage this darkening of the vascular bundles progresses rapidly. If infected potatoes are baked or boiled, the "black strings" which are commonly found in Kansas potatoes will readily separate from the flesh.

Symptoms of the Diseased Plant.

In the early stages of growth the leaves of diseased plants become slightly wilted or rolled. Sometimes only a single stalk in a hill will show this condition, while in other cases all the stalks become affected. Within a few days the stalks become dry. An examination of the stems will show a brown, dry condition which is the result of the invasion of the fungus. The roots are brown, somewhat hollow, and dry. In this way the wilt can be distinguished from Rhizoctonia or blackleg. The former causes little, dry, dark lesions on the underground stem, while blackleg causes a slimy, wet decay of the underground stem.

Life History.

The *Fusarium* wilt fungus occurs commonly in the potato fields and is perhaps more abundant in the sandy types of soils. The fungus producing this disease probably lives on some other plants besides the potato, such as weeds. The *Fusarium* wilt fungus has occurred abundantly in potato tubers grown in Kansas soils that were never in potatoes before. Continuous crops of potatoes will increase the amount of fungus in the soil. Primary infection probably occurs through the young feeding roots. The disease progresses through the stem attachments of the tubers, hence infection results at the stem end of the potato tuber. It is fortunate for the Kansas potato growers that this type of infection, which is very common in Kansas, does not spread any further in the field. Wilted plants in the field as a result of the *Fusarium* fungus occur only in very rare cases in Kansas. Infection, however, exists in the tubers, and if

they are not sold or consumed in July, the tubers will show the typical stem-end vascular blackening. The discoloration progresses or increases in direct proportion to the temperature and other storage conditions.

A second method of field infection may result from planting tubers showing discolored stem ends. It is not known definitely, however, how common this type of infection is in the seed used in Kansas. Most of the seed used in this state comes from Minnesota and North Dakota, while a lesser amount comes from Nebraska, Wisconsin, South Dakota, Montana and Colorado. The Fusarium

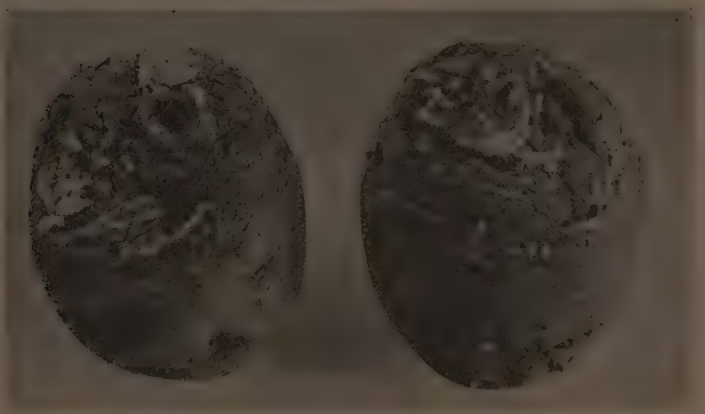

FIG. 8.—Dry rot and wilt infection showing outward appearance of the fungous growth.

wilt is harbored to varying degrees in the seed coming from all these states. When the seed has been stored over winter the stem-end infection develops and is noticed at the time the seed is cut in the spring. It is not known how much of this vascular browning is necessary to cause the typical wilt of the plant.

Control Measures.

Do not use tubers for seed which show badly discolored stem ends. This can be detected by removing a thin slice from the stem end. Seed potatoes should be stored at as low temperatures as possible without freezing—34° to 38° F. Kansas potatoes should be dug early. The disease in the tuber develops rapidly when potatoes are left in the soil over summer or when stored in a warm place. Potatoes should be sold or consumed as soon as dug; this avoids the de-

velopment of tuber infection. Practice rotation where possible. Grow a legume or other green crop so as to add humus to the soil. All seed should be treated in corrosive sublimate before planting.

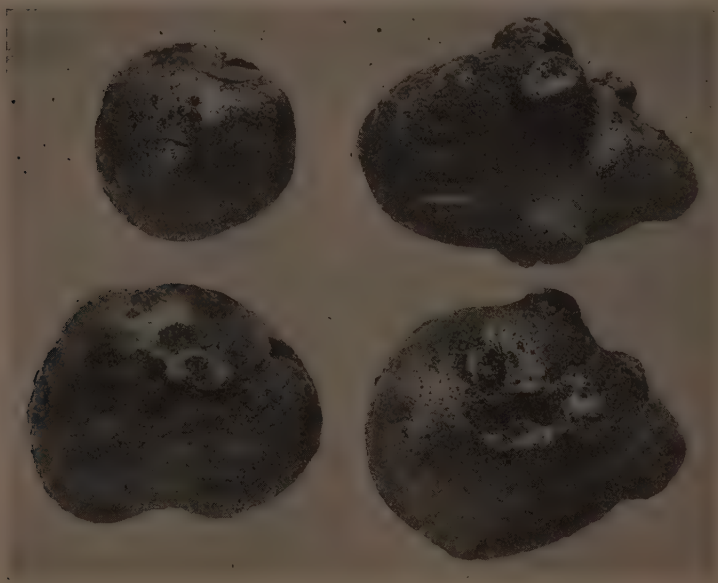

FIG. 9.—Potato scab on tubers. The deep scab is shown on the specimens on the left.

POTATO SCAB.

Symptoms on Tubers.

Potato scab is one of the oldest potato diseases with which the potato grower is acquainted. This disease is confined to the tuber, no other part of the plant being attacked. The skin becomes rough or crusty in spots. Sometimes the spots become deeply pitted. (Fig. 9.) It is called deep scab when it extends into the flesh. This disease causes a serious skin blemish, which reduces the value of the crop. In Kansas it also may afford an entrance for soft, watery decay.

Life History.

This organism is more or less common in all soils. The cause of this disease was for a long time unknown, but now it has been generally recognized to be the result of a specific fungous parasite. It seems to flourish best if soils are especially rich in organic matter,

or if heavy applications of manure have been added. For the most part potato scab results from planting scabby tubers without treatment. If scab has been severe in a crop, even after the seed has been treated, the indication is that the infection has come from the soil. In such a case it is a mistake to plant infested fields to potatoes the following year.

Control Measures.

The use of green cover crops will help to keep the soils slightly acid, a condition which is satisfactory for the potato crop but unfavorable for scab. Slightly acid soils seem to hold scab in check, while an alkaline condition makes its attack worse. Potatoes showing a large amount of scab should not be used for seed. No potatoes should be planted without receiving the corrosive sublimate treatment.

DRY ROT OF TUBERS.

Symptoms.

Dry rot attacks only the potato tubers, developing chiefly in storage. Small scratches or bruises are the starting place for this fungous infection. The rot is firm, dry to cheesy in consistency, and greyish white in color. Frequently the tufts of the mould will appear on the surface of the skin. (Fig. 8.) Badly infected tubers become shrunken in the affected areas. Eventually the tubers become completely dry, hard, and light weight during the latter stages. The seed used in this state generally shows a considerable per cent of dry rot in the spring.

Life History.

Dry rot is well known to potato growers. It is especially noticeable during the latter part of the storage period. Northern growers seem to find it impossible to dig their potato crop without bruising the tubers. Every scratch, cut or bruise on the surface of the tuber affords an entrance point for the *Fusarium* fungus which causes the dry rot. Seed potatoes used in Kansas show many slight injuries on the tuber. Infection has in most instances taken place from the organisms which are found in the dust adhering to the tubers. The dry rot develops rapidly in storage, especially if the temperatures are higher than 40° F. Badly infected tubers must frequently be thrown away, while in other cases from one-quarter to one-half of the tuber has to be cut away, since it is unsatisfactory for seed purposes. Partially rotted tubers, when used for planting, are apt to rot in the soil before the sprouts develop.

Control Measures.

Seed which is shipped into the state in the fall of the year should be stored at temperatures ranging between 34° and 38° F. Allow sufficient spaces between sacks for ventilation, since this tends to

FIG. 10.—Potato leaf showing early blight infection. Note the definite spots produced by the disease.

inhibit the development of dry rot. Do not use badly infected potatoes for seed. Tubers which show only a moderate amount of dry rot may be used if all the decayed portions are cut away. Treat all seed before cutting, using the corrosive sublimate treatment.

EARLY BLIGHT.

Symptoms.

The early blight of potatoes attacks only the foliage of the plant. It produces target-board-like spots, or concentric rings. (Fig. 10.) The spots range from one-eighth to one-half inch in diameter and are brown in color. The lowermost leaves are the first ones attacked and gradually all the leaves of the plant may show infection. It causes the potato leaf to turn brown and dry. In severe cases, early blight will completely destroy the foliage, leaving only the bare stalks. (Fig. 11.)

FIG. 11.—Potato field in 1915, practically destroyed by early blight.

Life History.

The critical time for early blight in Kansas is during the latter part of May and during June. It is caused by a specific fungous germ which enters the potato leaf. There are certain weather conditions which make conditions favorable or unfavorable for the spread of early blight. Continued spells of wet, muggy weather during May and June are ideal for an epidemic of early blight. In 1915 and 1916 prolonged wet spells in the spring were very favorable for early blight. Severe epidemics of early blight are not common in this state, but slight attacks are not infrequent in some counties.

Control Measures.

Timely applications of Bordeaux mixture are necessary if this disease is to be held in check. The foliage must be completly covered with this fungicide. The later sprays seem to be the most essential. No definite set dates can be given for such sprays, since seasons vary. The 4-5-50 and the 4-8-50 formulas seem to be the most satisfactory. Three or four applications may be necessary. Since early blight is extremely sporadic in its occurrence in Kansas, it is best for the grower to watch carefully for the first signs of early blight and be guided accordingly in his applications of sprays. Copper dusts are being used experimentally, but to date no results are available as to their control of this disease.

TIP BURN.[3]

Symptoms.

Tip burn and hopper burn are names which have been given to injuries which cause the margins of the leaves to turn brown, dry, and curl upward during the latter part of June and early July. The food-manufacturing power of the foliage is seriously diminished by the occurrence of the dead brown marginal injury. Affected plants virtually cease growing.

Life History.

The causes are not definitely known for all kinds of marginal injury on potato foliage. Those conditions which seem to be involved in the tip burn in Kansas are: (1) The injury said to be produced by the leaf-hopper insect, which is common in the potato fields some seasons. (2) A temperature and water relationship in the leaves and soil, in which the marginal regions are injured by excessive evaporation.

Control Measures.

Experimental investigations to date indicate that tip burn is reduced and the plants remain green longer when sprayed with Bordeaux mixture. The 4-5-50 and 4-8-50 formulas applied at least two times gives the best results. Copper dusts have not been used over a sufficiently long period in the experiments in Kansas to determine their effectiveness, although they appear to have merits.

3. Tip burn is used to designate the marginal leaf injury which occurs in this state, regardless of its cause.

POTATO DISEASE INVESTIGATIONS, 1917-1923.

REASONS FOR CONDUCTING EXPERIMENTS.

Surveys and studies of the diseases in the potato fields in the Kaw valley began in 1916 and 1917. Considerable complaint about poor stands and unsatisfactory yields was coming to the Kansas Agricultural Experiment Station. Seed treatment, or dipping the seed before planting, was practically a thing of the past, according to the replies from most of the potato growers. Those few who were treating said it did not seem to do any good, although fifteen or twenty years ago the formaldehyde dip was quite commonly used and was said to control the potato scab. For a period of about ten years, 1910-1920, therefore, seed treatment was very little used. It was evident from field studies which were made that the serious tuber-borne diseases, in their order of importance, were Rhizoctonia (black scurf), blackleg, and scab. The first two were responsible for a large percentage of the missing hills and consequently unsatisfactory yields. (Figs. 3 and 4.) In some counties the potato acreage showed no normal increase, while in others there was a gradual fluctuating decrease.

In 1917 and 1918 experimental and demonstrational plots were conducted to determine whether the corrosive sublimate treatment would be effective in controlling these diseases. Experimental evidence showed that the ordinary cold formaldehyde treatment which had been used for the control of potato scab was not a satisfactory treatment for seed potatoes which were being shipped in from the northern states. This was further confirmed by the experience of the potato growers who had discontinued the cold formaldehyde treatment.

Rhizoctonia and blackleg have become prevalent in the northern seed-producing states and it is to be expected that the seed will carry considerable external contamination. Conditions are such that it is practically impossible to grow disease-free seed in these regions; consequently some fungus will always be found on even the best seed potatoes. A minimum amount of the fungus should not disqualify them; proper seed treatment before planting will control the injury that results from a small amount of the fungus brought in on the potatoes.

Preliminary experiments were conducted in potato-seed treatment and spraying in the field, as well as greenhouse and laboratory studies during the seasons of 1916, 1917 and 1918. Cultural and

FIG. 12.—Treating potato seed on the farm of Mr. M. T. Kelsey (upper) and Skinner Brothers (lower).

life-history studies of the potato diseases occurring in the state were carefully worked out. Their prevalence and distribution in the state were also investigated. A better understanding of all these was imperative prior to undertaking the field experiments. It was thought advisable to begin the seed treatment and spraying experiments on a small scale in the vicinity of the Agricultural Experiment Station in order that frequent visits could be made to the field while the experiments were in progress. It seemed that a preliminary study would indicate those phases of the work and methods that would be best to follow in extensive, long-time experiments, with less loss of time and money. Later it was thought advisable to conduct the seed treatment and spraying experiments on a commercial scale in the best potato-growing districts, using such spray machinery and other equipment as one finds on the farms of the best potato growers.

RESULTS OF POTATO SEED TREATMENT.

Seed treatment plots, therefore, were started on the farms of Mr. M. T. Kelsey and Skinner Brothers, Topeka, Kan., Shawnee county, in 1918 for the control of Rhizoctonia, blackleg and scab. The corrosive-sublimate treatment was used. (Fig. 12.) This work was given considerable emphasis, since food conservation during this period was important. The results obtained from these plots seemed especially reliable because of the cultural methods followed by the growers.

TABLE II.—Effect of seed treatment on per cent of stand in the field.

(Experiments on farm of Mr. M. T. Kelsey, 1919)

VARIETY	Treatment	Date planted	Per cent stand
Minnesota Early Ohio	Treated	March 28	95
Minnesota Early Ohio	Untreated	March 28	73
Minnesota Early Ohio	Treated	April 14	96
Minnesota Early Ohio	Untreated	April 14	66
Minnesota Early Ohio	Treated	April 14	97
Minnesota Early Ohio	Untreated	April 14	50

This as well as other experiments seems to show that the late-planted potatoes are much more injured by Rhizoctonia and blackleg than early-planted. In a second experiment, which was run primarily for a yield test and to compare early with late planting, the following results were obtained:

TABLE III.—Effect of delayed planting on yield of treated and untreated seed.
(Experiments on farm of Mr. M. T. Kelsey, 1919.)

VARIETY	Treatment	Date planted	Yield in bushels per acre	Remarks
Minnesota Early Ohio	Treated	March 28	195.7	Seed cut Mar. 26 and planted March 28
Minnesota Early Ohio	Untreated	March 28	173.0	
Minnesota Early Ohio	Treated	April 14	135.0	Seed cut Mar. 26 and planted April 14
Minnesota Early Ohio	Untreated	April 14	69.0	

In both Tables II and III each treatment was sufficiently large to be dependable. About one-half an acre was devoted to each separate treatment. A number of potato growers were present at digging time to see the results of seed treatment and to examine the plots which were run, to compare the yield of certified or registered seed with commercial seed of the two varieties, Early Ohio and Irish Cobbler. The results definitely proved the value of seed treatment, and in 1920 and 1921 the acreage of seed that was treated before planting in Shawnee county grew rapidly. (Figs. 13 and 14.) It seemed necessary, however, to conduct seed-potato treatment plots in other counties where potatoes were extensively grown and where the growers could observe the results. Therefore, a number of experimental plots were planted in Wyandotte, Douglas, Ford and Pottawatomie counties. These experiments were conducted on the farms of prominent potato growers where seed treatment was not generally followed. The growers themselves took the leading part in all the tests, and with the aid of men from the Agricultural College and county agricultural agents, definite records were taken on the difference in yield from treated and untreated seed. It should be mentioned that the seed which was generally planted in the spring of 1922 was badly diseased and the cool, wet spring was favorable for severe infection where the potato-disease organisms were present. The size of the plots varied from one-half to 10 acres each.

FIG. 13.—Potato-treating outfit used by Mr. Grant E. Kelsey, Shawnee county.

FIG. 14.—Potato-treating outfit used by Mr. William Shideler, Shawnee county.

TABLE IV.—Results of coöperative potato seed treatment experiments, 1922.

COUNTY	Grower	Yield from treated plot, in bushels per acre	Yield from untreated plot, in bushels per acre	Increase due to treatment, in bushels per acre
Wyandotte	Ed. Bigham	160.0	119.0	41.0
Wyandotte	B. S. and J. S. Stephens	88.0	47.0	41.0
Wyandotte	Jas. Trant	267.0	192.0	75.0
Wyandotte	Chas. Speaker	172.0	136.0	36.0
Douglas	F. V. Lewis	188.0	144.0	44.0
Douglas	A. J. Parnell	147.0	81.0	66.0
Douglas	Wm. Stiner	180.0	140.0	40.0
Shawnee	G. Kelsey	139.0	95.0	44.0
Ford	Hulpieu & Fischer	250.0	243.0	7.0
Wyandotte	W. G. Philibert	110.0	40.0	70.0
Shawnee	C. V. Cochran	174.4	89.2	85.2
Pottawatomie	R. N. Spangler	130.0	90.0	40.0
Total		2,005.4	1,416.2	589.2
Average		167.1	118.0	49.1

TABLE V.—Results of coöperative potato seed treatment experiments, 1923.

COUNTY	Grower	Yield from treated plot, in bushels per acre	Yield from untreated plot, in bushels per acre	Increase due to treatment, in bushels per acre
Shawnee	Oliver Brothers	181.0	141.0	40.0
Douglas	Wm. Stiner	240.0	192.0	48.0
Douglas	W. H. Hayden	206.5	163.7	42.8
Douglas	E. W. Heck—cowpea cover-crop ground	256.0	243.0	13.0
Douglas	E. W. Heck—rye cover-crop ground	221.0	192.3	28.7
Leavenworth	Omar Browning	264.0	244.0	20.0
Douglas	Brune Brothers (average on two plots)	135.0	120.0	15.0
Douglas	Clarence Pine	291.0	161.0	130.0
Wyandotte	Will Curth	300.0	270.0	30.0
Wyandotte	C. N. Miller & Son	376.0	314.0	62.0
Wyandotte	C. Speaker	122.0	89.0	33.0
Wyandotte	James Trant	195.6	146.6	49.0
Jefferson	Wm. Gordon	147.4	108.0	39.4
Jefferson	Howard Good	181.0	165.0	16.0
Jefferson	Sherman Bell	142.4	101.0	41.4
Wyandotte	John Stephens	255.0	161.0	94.0
Ford	Jim Porter	103.0	51.0	52.0
Ford	Lon Wilkinson	38.0	23.0	15.0
Shawnee	L. H. Neiswender	81.9	54.6	27.3
Shawnee	Clyde Dennon	156.0	73.0	83.0
Total		3,892.8	3,013.2	879.6
Average		194.6	150.7	44.0

A number of potato growers had plots of treated and untreated potatoes in 1923, but definite yield records were not taken. These men have made the following statements:

Herman Theden, Wyandotte: Increase at least 30 per cent.

H. G. Powell, Douglas: Treated about doubled untreated.

F. Blechel, Douglas: Treated much better than untreated.

James Roe, Douglas: Well satisfied with treatment.

THE CORROSIVE SUBLIMATE POTATO SEED TREATMENT.

This is sometimes called the mercuric chloride treatment. It has been used up to the present with very satisfactory results. Experiments are still in progress to determine if modifications of this treatment, or the substitution of the hot formaldehyde treatment, has advantages over the standard corrosive sublimate treatment. Until such improvements can be recommended, the grower had better continue with the method that has given him satisfactory returns.

1. Preparation of Solution.—Prepare the solution by mixing four ounces of corrosive sublimate, which can be secured from the local drug store, in 30 gallons of water. Powdered corrosive sublimate is preferred, and should first be mixed with one quart of warm water in a glass jar, since it dissolves more quickly in hot water. If desirable, the corrosive sublimate can be dissolved rapidly in cold or lukewarm water by adding an equal amount of ammonium chloride. When completely dissolved add enough water to make 30 gallons. Corrosive sublimate is a deadly poison and must be kept away from children and animals. It will not injure the hands. Treated seed is poisonous and must not be eaten or fed to stock.

2. Containers.—Do not use metal vessels or containers for this solution, since it corrodes metals and the value of the poison is thus quickly destroyed. Barrels, wooden tubs or concrete vats may be used. Recent experiments show that it is poor practice to use sacks in this treatment. The sacks weaken the solution rapidly and render the treatment ineffective. It is best to put the tubers directly in the solution or in wooden baskets or crates. Never treat cut potatoes, since there is some danger of injury and the solution will deteriorate very rapidly. If barrels are used as containers, wooden bushel baskets with ropes attached can be used. In this way, two bushel baskets full can be treated in a barrel at a time. If a wooden or concrete tank is used, wooden crates are very convenient and serve the purpose well.

3. Renewing the Solution.—The solution should not be used for more than three batches of potatoes, unless corrosive sublimate is added each time. Corrosive sublimate should be added at the rate of one-half to five-eighths of an ounce to each 30 gallons of water after each treatment. This is on the basis of the one and one-

half hours treatment. If the 30-minute period is used, only one-eighth of an ounce need be added for each four bushels treated. **This addition should not be made more than five times, and then the tank should be drained and thoroughly cleaned.** For convenience, a stock solution of one ounce of corrosive sublimate to one quart of water can be made up. When corrosive sublimate is added care must be taken to have the treating solution made up to its original volume. The solution should not be used if it has stood overnight, for it weakens on standing. Dirt weakens the solution rapidly, consequently excessive amounts of it should be avoided.

4. Length of Treatment.—The best results with this treatment in Kansas have been obtained when the one and one-half hours treatment was given, and this is strongly advised in place of shorter periods. However, if that length of time cannot be given, the potatoes should be left in the solution at least one-half hour. Recent experiments have shown that it helps very materially to wet the potatoes a few hours or a day before the treatment is given. This can be done by wetting them in the sack by means of a hose. This wetting soaks up the fungus masses and they will be killed more quickly when the treatment is given. This is especially advantageous for the one-half-hour period.

5. Treating Sprouted Seed.—Badly sprouted seed should not be treated. By badly sprouted seed is meant seed that has sprouts one-fourth of an inch in length or longer. (Fig. 15.) There are usually one or two sprouts at the blossom end that are further developed than the others, but this should not prevent one from treating. If the sprouts all over the potato are far advanced, then seed treatment should not be practiced, for injury to the sprouts is liable to result. (Fig. 15.) If seed is sprouted so there is doubt whether to treat or not to treat, the one-half-hour treatment is advisable.

6. Cost of Treating Seed.—Records on the cost of seed treatment show that, on an average, it costs very close to $1 per acre. This includes labor, equipment and chemicals.

7. Storing Treated Seed.—Treated seed should not be stored unless thoroughly dried. It is best to plant soon after treatment. Many growers treat, cut and plant on the same day. This has given satisfaction. Growers not familiar with seed treatment should arrange with their county agricultural agents for a demonstration.

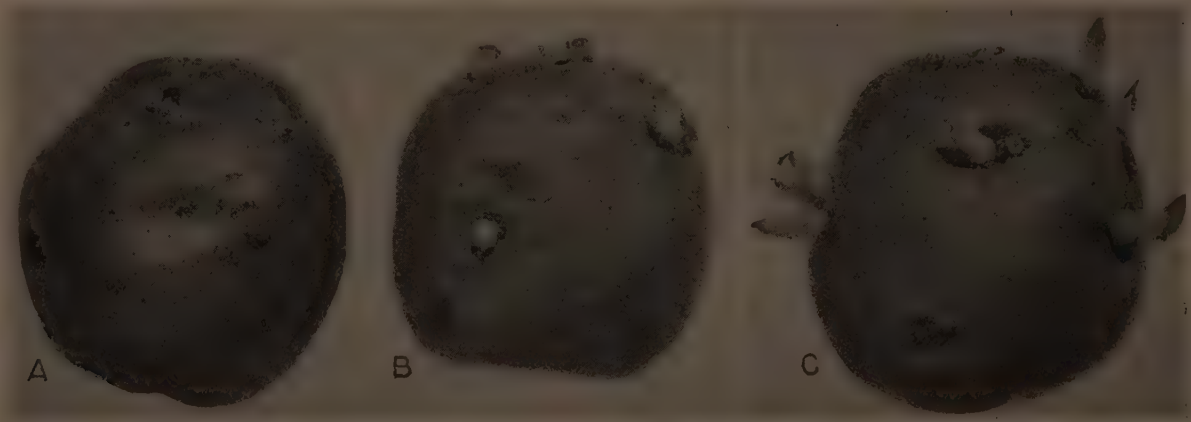

FIG. 15.—Potatoes sprouted to various degrees. Care should be taken to avoid injury in treating with the corrosive sublimate treatment. (A) Potatoes in this condition can be given the 1½-hour treatment. (B) Potatoes sprouted as much as these should be treated only one-half hour. (C) Such potatoes as these are too badly sprouted to be treated at all.

SUMMARY OF POTATO SEED TREATMENT EXPERIMENTS, 1918-1923.

1. The fact that the corrosive sublimate seed treatment is effective in preventing a large part of the loss from the diseases Rhizoctonia, blackleg and scab is well established by the results of the experiments reported in Tables II, III, IV and V.

2. The increase in yield and the improved appearance of the potatoes due to this treatment show that it is a practice which no grower can afford to omit.

3. Potato seed treatment is rapidly increasing in this state. In Shawnee county in 1922 and 1923 over 90 per cent of the potato acreage in this county was planted to treated seed.

4. The percentage of treated seed in the state, however, is still small in comparison to the amount planted. In 1923 it is estimated that seed for not over 40 per cent of the total commercial acreage was treated before planting.

SPRAYING EXPERIMENTS 1918, 1919, 1920.

Spraying the potato crop with Bordeaux mixture has never been a general practice in Kansas, but the use of liquid or dust arsenicals for the control of potato beetles has long been a necessity. Bordeaux mixture is primarily a fungicide for the control of plant diseases attacking the foliage. In recent years it has been found that Bordeaux mixture is apparently acting as a repellent to such insects as the leaf hopper. Furthermore, in some states it is being found that Bordeaux mixture, for some unexplained reason, is increasing the yield of sprayed plants, even though foliage diseases are not present. Such states as New York, Pennsylvania and New Jersey have obtained increased yields from Bordeaux sprays, even though the foliage diseases (late blight, early blight, and tip burn) have not been present. This has led many growers to refer to it as a "tonic" for the potato crop. It has long been established that Bordeaux mixture will control late blight and is of importance in lessening the damage from early blight. Late blight has never been found in the potato fields of this state and there seems little reason to expect that it will occur on account of climatic and soil conditions which seem to suppress its development. Early blight, however, does occur, but generally the injury is slight to moderate. Most seasons it is practically absent. There is no method by which the occurrence of this disease can be predicted. Cool, wet weather the latter part of May and up to the middle of June are favorable for its spread. In view of the sporadic occurrence of early blight, the lack of information as to whether Bordeaux mixture will increase the yield during seasons

when early blight does not occur, and on account of inadequate information as to whether tip burn and hopper burn can be reduced by this spray, it seemed necessary to attempt to discover some definite facts concerning the value of Bordeaux mixture in relation to the potato crop in Kansas.

In 1918 and 1919 preliminary spraying experiments were conducted at Manhattan. The available land was limited and not well suited to potato culture, therefore the spraying experiments were not conducted on an extensive scale. A satisfactory spraying outfit was not available, and it was evident that a knapsack sprayer could not be used in experimental work. The general results for these seasons can be briefly stated. In 1918 a half-acre plot was planted with Early Ohio and Irish Cobbler treated seed. The Bordeaux sprays applied were, 2-3-50, 3-4-50, and 4-5-50 plus lead arsenate. Three or four applications were given in different series. Little or no difference was found between sprayed and unsprayed plots. The results were not consistent, due, very probably, to soil differences and inadequate facilities for conducting the experiments. No early blight was present in 1918, although tip burn appeared to some extent.

In 1919 a similar experiment was conducted at Manhattan. A general summary of the experiments showed that the 4-5-50 Bordeaux gave the best results, the 3-4-50 the next best, and the 2-3-50 the least favorable results. Early blight was absent, but tip burn was present to a moderate extent.

In 1920 it was thought advisable to conduct the spraying projects in Shawnee county, where conditions would be more favorable for growing the potato crop. Coöperative arrangements were made with Mr. M. T. Kelsey and Skinner Brothers of Topeka. The first experiments were conducted on these farms and have continued to date in the case of Mr. M. T. Kelsey. On account of a very unfavorable season, the plots of Skinner Brothers were not dug until August. It did not seem advisable to depend upon these data on account of this delay; therefore the records were not taken. Power sprayers have been used for the experiments on the farm of Mr. M. T. Kelsey. (Fig. 16.) The rows were about one-fourth of a mile in length and the entire experiment involved ten acres. Sprays were applied to both the Irish Cobbler and Early Ohio varieties. The following strengths of Bordeaux mixture were used: 2-3-50, 3-4-50, and 4-5-50. Both varieties were given three or four applications of spray. The first spray in 1920 was applied June 3 and 4; the second, June 11 and 12; the third, June 21; and the fourth June 28.

FIG. 16.—Spraying the potato crop with Bordeaux mixture on the farm of Mr. M. T. Kelsey, Shawnee county.

Since actual dates mean little on account of seasonal conditions, an attempt was made to apply the sprays at various stages in the development of the potato plant. These were approximately as follows:

First spray, when the plants were six to eight inches tall.
Second spray, eight to ten days later.
Third spray, when the plants were beginning to blossom.
Fourth spray, just when the vines ceased growing.

The season of 1920 was an unusually favorable one for the potato crop, but unfavorable for the experiment outlined. Neither early blight nor tip burn was present in the experimental plots—an unusual condition for Kansas, since tip burn generally appears. This undoubtedly accounts for the lack of any outstanding differences between the sprayed and unsprayed plots. (Table VI.) Some of the unsprayed or check plots showed higher yields than the sprayed plots, but this may be accounted for by soil variation when the probable error of the check plots is taken into consideration.

The probable error of the calculated increase over the unsprayed plots (Tables VI and VII) was determined by the formula $E\,d = (1/\sqrt{2})\ (.6745)\ \sqrt{\frac{\Sigma d^2}{n-1}}$ based upon the variability of the check plots. It is realized that the number of plots in these experiments is not very great, and therefore it may raise the criticism that the use of the probable-error concept is therefore not justified. However, it is felt that, admitting the limitations, a better measure of the reliability of the results can be secured with its aid than if disregarded entirely.

POTATO SPRAYING EXPERIMENTS, 1921.

The experiments were conducted in much the same manner as those in 1920. The plots were made larger to facilitate digging and spraying operations, each plot being approximately an acre in size. A few changes in the general plan of 1920 were made. The 2-3-50 Bordeaux plots were omitted because of the poor results from this spray in the preliminary experiments at Manhattan and in the experiments in Shawnee county in 1920. Two plots were added to the experiments, which were sprayed with the 4-8-50 formula. Data were desired relative to the value of an increased amount of lime, which has been thought to act as a repellent to the leaf hopper and an aid to the reduction of tip burn. The plots were sprayed with a Bean power sprayer, having a pressure of 150 to 175 pounds and equipped with two nozzles to the row and spraying ten rows at a time. Approximately 100 gallons were applied to the acre. Those

plots sprayed four times had applications on May 23, June 3, 9 and 21. Those sprayed three times had the spray omitted on May 23. Leaf hoppers were present the latter part of the season. An average amount of leaf-hopper injury and tip burn was present. The results for 1921 are recorded in Table VI. Again the sprayed plots showed no outstanding or consistent differences from the unsprayed, although the results were more consistent and slightly in favor of the sprayed plots. The Early Ohio sprayed plots showed an average increase of 15.7 bushels per acre, or 10.5 per cent, while the Irish Cobbler sprayed plots showed an average increase of 21.8 bushels per acre, or 8.2 per cent. When the probable error of the check plots is applied there are a few plots that show favorable results. The results, however, as a whole indicate that the application of Bordeaux is still of questionable value.

POTATO SPRAYING AND DUSTING EXPERIMENTS, 1922.

In these experiments the Early Ohio variety was omitted, being replaced entirely by the Irish Cobbler. This was thought advisable for the reason that the Irish Cobbler variety was rapidly replacing the Early Ohio in the vicinity in which the experiments were conducted, and because no difference could be seen in the behavior of these two varieties with reference to the sprays applied in other seasons. Two plots were added to the experiments on the farm of Mr. M. T. Kelsey; one copper dust plot to take the place of a liquid fungicide, and one arsenical dust plot to determine the relative efficiency of the liquid and dust arsenicals in the control of the Colorado potato beetle.[4] The results on insect control are included here in order to give a more exact basis for calculating the probable error. A plot was also included to determine the value of commercially prepared Bordeaux mixture in comparison with the liquid homemade Bordeaux.

Three sprays were applied, the first May 25, the second June 2, the third June 15. The liquid sprays were applied with the same equipment and at the same rate of application as in 1921. The copper dust was applied with a Johnson traction duster, one nozzle to the row, at the rate of 22 pounds to the acre for each application. This dust was a commercial compound known as Dosch B16. The results tabulated in Table VI show a somewhat consistent increase in yield in favor of the plots that received the fungicidal liquid sprays, with the exception of the plot that was sprayed with the commercially prepared Bordeaux mixture. Omitting this plot, the average increased yield from the Bordeaux mixture plots was 29.7

4. Prof. G. A. Dean of the Department of Entomology coöperated in these experiments in 1922, and information regarding the results on insect control can be secured from him.

bushels per acre, or about 10 per cent. This seems significant in view of the fact that early blight was practically absent. Leaf hoppers were present almost the entire time, being very abundant from the middle to the end of the crop season. The vines of the sprayed plots remained green longer than the unsprayed plots. This may explain the increase in yield both for the sprayed and dusted plots and for the large increase in yield on the plot that received more than the normal quantity of lime. The 4-8-50 Bordeaux plot showed the greatest increase in yield, while the copper dust plot showed the second largest increase. The copper dust contained about 70 per cent lime as a carrier. The loss of 2.9 bushels from the plot sprayed with commercial Bordeaux is not significant when the probable error of the checks, which is ± 12.5 bushels, is taken into consideration. The results indicate that commercial Bordeaux is of doubtful value. The copper dust used in this experiment in 1922 looks promising. It is of course too early to state what its value will be in Kansas as compared to the homemade liquid Bordeaux sprays, and several years' results must be obtained before a definite statement can be made. This same compound showed the most favorable results in a dusting experiment on another farm in 1922. (Table VII.)

POTATO SPRAYING AND DUSTING EXPERIMENTS, 1923.

The spraying experiments for the control of foliage diseases and insects were conducted in 1923 with Mr. M. T. Kelsey, Topeka, as in previous seasons. The plots were arranged as in 1922 and the same mixtures were applied. A power sprayer having three nozzles to the row instead of two was used.

The results of these experiments are reported in Table VI. A plot was also included to which copper dust was applied, as well as two more checks. However, these plots suffered badly from heavy rains, so that records are not included. The results of the experiments in 1923 do not show an increase in yield on plots receiving an application of Bordeaux mixture. Some of the plots, in fact, show a loss. This, however, is not significant when the probable error of the check plots, which is ± 46.7 bushels, is taken into consideration. In the same way the slight increase of some of the plots can be explained. The results, however, are what we would expect in a season such as prevailed in the Kaw valley in 1923. Early blight and leaf hopper were not present until very late in the season, so that little injury resulted. Furthermore, it should be stated that the fourth spray that was originally planned was omitted for the reason that excessive rains prevented the application. Had this been applied the results might have been somewhat different.

TABLE VI.—Summary of coöperative potato spraying and dusting experiments on the M. T. Kelsey farm, 1920–1923.

TREATMENT	Formula	1920				1921				1922		1923		Calculated average increase per acre (*b*)	
		Irish Cobbler		Early Ohio		Irish Cobbler		Early Ohio		Irish Cobbler		Irish Cobbler			
		Yields per acre	Calculated increase per acre (*a*)	Yields per acre	Calculated increase per acre (*a*)	Yields per acre	Calculated increase per acre (*a*)	Yields per acre	Calculated increase per acre (*a*)	Yields per acre	Calculated increase per acre (*a*)	Yields per acre	Calculated increase per acre (*a*)		
None	Check (*d*)			274.0											
4 sprays Bord.	2–3–50	288.4	35.0 loss	287.0	2.7										
None	Check	323.4		294.6										16.2 loss	±10.6
3 sprays Bord.	2–3–50	296.0	10.2 loss	250.8	31.5 loss										
None	Check	288.9		270.0				122.58						20.9 loss	±10.6
4 sprays Bord.	3–4–50	315.8	19.0 loss	296.0	13.7	310.4	20.7	158.83	27.6						
None	Check	304.8		294.6		289.7		139.88		320.1		326		20.3	±10.2
3 sprays Bord.	3–4–50	293.0	19.9 loss	325.0	29.2	310.9	24.6	191.80	43.6	332.6	12.8	347	0.5 loss	15.0	±10.1
None	Check	321.0		297.0		282.9		156.58		319.6		369			
4 sprays Bord.	4–5–50	302.0	9.7 loss	309.0	25.5	340.9	50.0	179.58	22.2					22.0	±10.2
None	Check	302.4		270.0		299.0		158.25							
3 sprays Bord.	4–5–50	277.2	13.1 loss	300.8	32.4	279.1	5.4 loss	(*c*)160.00	5.9	364.4	32.5	347	23.0 loss	4.9	±10.1
None	Check	278.1		266.7		270.0		(*c*)150.00							
4 sprays Bord.	4–8–50					285.5	34.2	(*c*)155.90	6.5 loss					13.9	±17.5
None	Check					232.7		(*c*)174.81		344.2		371			
3 sprays Bord.	4–8–50					231.8	6.5	(*c*)158.50	0.7	378.7	43.9	388	17.5	17.2	±14.9
None	Check					218.0		(*c*)140.90		325.4		370			
3 sprays Bord.	Com. prepared 4–4–50									314.2	2.9 loss	402	23.0	10.1	±24.2
None	Check									308.7		388			
3 dusts copper	Dosch B16									345.9	39.7				±12.5
None	Check									303.7					
2 Dust Insec.	Lead, Paris green, hydrated lime														
None	Check									331.7	22.0	325	3.0	12.5	±24.2
Probable error of the difference based upon check plots	$E d = (\sqrt{2})\ (.6745)\ \sqrt{\frac{\Sigma d^2}{n-1}}$		±16.8		±13.0		±31.2		±15.8		±12.5		±46.7		
		315.7		256											

(*a*) Increase obtained by averaging the yield of two adjacent check rows, and subtracting the result from the yield of the sprayed row.

(*b*) The algebraic sum divided by the number of results was calculated as the average increase. The probable error of the average increase was calculated by the formula $E d = \frac{\sqrt{E_1^2 + E_2^2 + \ldots . E_n^2}}{n}$

(*c*) Heavy rains had produced some irregular areas in these plots.

(*d*) All check plots were sprayed only with arsenicals for potato beetles. All the other plots received sprays containing arsenicals for potato-beetle control.

DISCUSSION OF THE COOPERATIVE DUSTING EXPERIMENTS, 1922-1923.

A large number of growers in the Kaw valley use arsenicals in the form of dust to control the Colorado potato beetle. Their enthusiasm for the dusting method was so pronounced that a knowledge of the relative merits of fungicidal dusts seemed imperative. Accordingly, plots were included in the experiments in 1922 on the farms of Messrs. G. E. Kelsey and M. T. Kelsey, Topeka.[5] The results on insect control are included here in order that all the checks may be recorded, which affords a more exact basis for calculating the probable error.

TABLE VII.—Results of the coöperative dusting experiments on the farm of Mr. Grant E. Kelsey, 1922 and 1923.

TREATMENT	Formula (a)	1922		1923	
		Yield per acre, bushels	Calculated increase per acre, bushels	Yield per acre, bushels	Calculated increase per acre, bushels
Check	E	291.5	.....	290.0	.....
Copper dust	G	349.8	57.1	291.5	5.2 loss
Check	E	293.9	.....	303.3	.....
Dosch B15	B15	249.7	15.9 loss	297.6	12.8 loss
Check	E	237.3	.....	317.5	.....
Gliddens Bordeaux	H	290.5	25.6	297.0	6.4 loss
Check	E	292.5	.....	289.2	.....
Calcium arsenate	I	314.6	14.4	292.0	0.7 gain
Check	E	307.9	.....	293.5	.....
Probable error of the difference based upon check plots: $Ed = (\sqrt{2})(.6745)\sqrt{\frac{\Sigma d^2}{n-1}}$		.....	±26.0	.....	±11.4

(a) Formulas:

E. Paris green 5 lbs.
Arsenate of lead 10 lbs.
Hydrated lime 85 lbs.

G. Parid green 5 lbs.
Arsenate of lead 10 lbs.
Dosch B16 80 lbs.
Hydrated lime 5 lbs.

I. Calcium arsenate 20 lbs.
Hydrated lime 80 lbs.

Dosch B15—
Monohydrated copper sulphate 20 lbs.
Calcium arsenate 20 lbs.
Hydrated lime 55 lbs.
Sticker 5 lbs.

H. Paris green 5 lbs.
Arsenate of lead 10 lbs.
Glidden's dry B. M. 60 lbs.
Hydrated lime 5 lbs.

In these plots three copper dusts were compared; a product known as Dosch B16, another as Dosch B15, and a third known as Gliddens Bordeaux, which is a commercially prepared mixture intended for use in a liquid spray. All plots received arsenical dusts for the control of potato beetles. The copper dusts were applied at the rate of 22 pounds to the acre with a Johnson traction duster, one nozzle to the row. Dusts were applied May 25, June 2 and June 15. Results are recorded in Table VII. Dosch B16 was the

5. Prof. G. A. Dean of the Department of Entomology coöperated in this work.

most efficient copper dust. It gave a significant increase on the farm of Mr. M. T. Kelsey. The Dosch B15 and Glidden's Bordeaux showed no appreciable influence. When the probable error of the check plots, which is ± 26.0 bushels, is considered, they appear to be of doubtful value. These experiments will be continued for a period of years.

In 1923 no increase in yield was obtained by the use of the copper dusts. This can perhaps be accounted for by the seasonal conditions as explained under the 1923 spraying experiments.

COST OF APPLICATION OF BORDEAUX SPRAYS AND COPPER DUSTS.

From a practical viewpoint it is necessary to consider the cost of application of Bordeaux sprays and copper dusts in order to determine whether it is advisable to apply them. Sprays and dusts may show increased yields, but if the increase is not sufficiently large to more than defray the expense of application, their use is not sound economy. Considering the equipment used in these experiments, the wages, and the cost of materials calculated at prices prevailing at the time and place where the experiments were conducted, the expense connected with the application of the sprays was as follows:

Liquid Homemade Bordeaux Mixture.

4-5-50 formula—rate 100 gallons per acre:	
8 lbs. of bluestone at 10c.	$0.80
10 lbs. of lime at 1c.	.10
1 hour time, man and team, at 70c.	.70
1 hour time, helper	.30
Gasoline, oil, interest on investment, depreciation of equipment[6]	.49
Total cost per application	$2.39

At a cost of $2.39 per application, three applications would cost $7.17 per acre. This would mean that, with potatoes selling for 75 cents a bushel, one would have to have at least a ten-bushel average annual increase to pay for the sprays.

Copper Dusts.

Approximately 4-5-50 formula—rate 22 lbs. per acre:	
22 lbs. copper dust at 10c	$2.20
¼ hour time man and team at 70c	.18
Interest on investment and depreciation on equipment[7]	.17
Total cost of application per acre	$2.55

6. Figured on the basis of an outfit valued at $400 and used to spray 100 acres three times per season for four seasons.

7. Figured on the basis of an outfit valued at $165 and used to dust 100 acres three times per season for four seasons.

Thus at a cost of $2.55 per application, three dust applications would total $7.65 per acre. This would mean that, with potatoes selling for 75 cents per bushel, at least a ten-bushel average annual increase would be required to pay for this dusting.

SUMMARY OF POTATO SPRAYING EXPERIMENTS, 1918-1923.

The results of the experiments on potato spraying with fungicides in Kansas for the past five years show that—

1. Seasonal conditions determine to a large degree the value of the application of a fungicide.

2. If sprays are to be applied, the 4-5-50 or 4-8-50 Bordeaux mixture should be used rather than the 2-3-50 or 3-4-50 strengths.

3. Large increases in yield do not seem probable as a result of the application of a fungicide except during seasons of serious epidemics of early blight or tip burn. Spraying the potato crop with Bordeaux mixture lessens the amount of tip burn and keeps the vines green for a longer period. This has resulted in increased yields some seasons.

4. Spraying potatoes with a fungicide must be looked upon as an insurance. It acts as a protection during seasons when early blight and tip burn may become serious.

5. Considering the results obtained in spraying with Bordeaux mixture for the period 1918-1923 it would seem that the returns have been too small to warrant the cost. It is realized that these experiments cover only a five-year period and that seasons and conditions might occur when different results would be obtained.

6. Experience has shown that if sprays are to be applied, good equipment and a pressure of at least 150 pounds are absolutely essential. The average liquid spraying outfit used by the potato grower is not adequate and will not give as favorable results as were secured in these experiments.

7. Bordeaux sprays applied between the time the plants show flower buds and the last week in June are considered the most important.

EXPERIMENTS WITH CERTIFIED AND COMMERCIAL SEED.

It is being recognized that some strains of seed potatoes in a variety like Irish Cobbler are better in yielding qualities than other strains. Where a large number of such strains are grown under the same conditions, it becomes possible to select strains which seem to have outstanding merits. Definite information is not available regarding how much reliance can be placed on increased yields due to heritable characters, such as freedom from the so-called degenerative diseases, and how much due to the environmental conditions under which the different strains are grown. It appears that some strains are producing higher yields and are especially adapted to definite localities; therefore, in purchasing seed potatoes, these things should be kept in mind. Some seed-potato growers who are specializing in seed production are giving strain testing considerable attention at the present time, and for this reason some seed potatoes seem superior to others. Such work, together with greater care in producing seed relatively free of fungous and bacterial diseases, is commanding the attention of growers of certified seed potatoes. Experiments were conducted in Kansas to determine whether or not certified seed is superior to uncertified or commercial stock. Information was also sought regarding strains of seed that were best adapted to Kansas conditions.

HOW CERTIFIED SEED IS PRODUCED IN NORTHERN STATES.

In order that a grower can be listed as a producer of certified seed it is necessary for him to make application to the proper state official for inspection service both in the field and in the bin. The state inspector makes one or two field inspections during the growing season and one during digging time. If he finds that the potatoes conform to the standards set for seed certification, he issues a certificate of inspection. The certified or registered potatoes are then sacked and labeled with a definite tag **indicating the name of the grower and stating definitely that the sack contains certified seed.**

The standards set by the Northern states are in general as follows:

1. Freedom from varietal mixtures in the field and conformity to correct vine and tuber characteristics of the variety.

2. Conformity to such desirable commercial grades as can be secured through sorting.

3. Freedom from the fungous diseases black wart and powdery scab.

4. Freedom from serious infection with any other diseases, such as Rhizoctonia, scab, blackleg, and mosaic.

In addition, some states are requiring that the grower raise a seed plot from which he will select the strain of potatoes as seed for his main seed potato crop.

RESULTS OF CERTIFIED, COMMERCIAL SEED, AND STRAIN TESTS.

Table VIII gives the data obtained from experiments in this state in 1921 and shows that—

1. There was an increase yield of 50.12 bushels from the certified Early Ohios over uncertified Early Ohios planted side by side on the same farm.

2. There was a wide variation among the four strains of Early Ohio from Nebraska.

3. Bliss Triumph is not so well adapted to Kansas conditions as are Irish Cobbler and Early Ohio.

4. The Nebraska seed used in the experiments in 1921 seemed as good as Minnesota seed for Kansas.

Table IX gives the data for the experiments in 1922. A study of this table shows that—

1. The certified seed shows an average yield of 36 bushels per acre more than the commercial seed.

2. The seed from the various states show differences in yield. On some farms this was quite marked, while on others little or no difference can be noted.

3. There seems to be a great variation in strains of potatoes of the same variety from the same state.

4. Several states are producing seed adapted to Kansas conditions.

TABLE VIII.—Results of coöperative experiments with Nebraska and Minnesota seed potatoes, 1921.

Variety	Strain No.	Source of seed	Farm of H. V. Cochran, Silver Lake, Kan.		Farm of A. J. Parnell, Lawrence, Kan.	
			Treated or untreated	Yields per acre	Treated or untreated	Yields per acre
				Bushels		*Bushels*
Early Ohio...	1	Minnesota certified..	Treated.....	126.1	.....	.....
Early Ohio...	1	Nebraska certified...	Treated.....	108.0	Treated.....	261.11
Early Ohio...	2	Nebraska certified...	Treated.....	128.0	Treated.....	241.40
Early Ohio...	3	Nebraska certified...	Treated.....	128.6	Treated.....	206.00
Early Ohio...	4	Nebraska certified...	Treated.....	140.0	Treated.....	141.40
Triumph.....	1	Nebraska certified...	Treated.....	87.6	Untreated....	129.46
Triumph.....	2	Nebraska certified...	Treated.....	47.1	Untreated....	144.81
Triumph.....	3	Nebraska certified...	Treated.....	28.6	Untreated....	52.60
Irish Cobbler,	1	Minnesota certified..	Treated.....	137.0	.....	.....
Irish Cobbler,	1	Nebraska certified...	Treated.....	81.8	Untreated....	164.56
Early Ohio...	1	Minn. commercial...	.....	.....	Treated.....	171.14
Early Ohio...	1	Minn. commercial...	.....	.....	Untreated....	153.59

TABLE IX.—Results of coöperative experiments with certified and commercial potato seed, 1922 (*a*).

VARIETY	Source	Kind of seed	Yields per acre—bushels			
			Farm of H. V. Cochran, Silver Lake, Kan.	Farm of A. J. Parnell, Lawrence, Kan.	Farm of Chas. Speaker, Turner, Kan.	Farm of Hulpieu & Fischer, Dodge City, Kan.
						Irrigated
Early Ohio	Market—Minnesota (*b*)	Commercial		103.0	116.0	238.0
Early Ohio	Albert Peterson, Rhinelander, Wis	Certified	216	187.5	148.2	275.0
Early Ohio	Market—Minnesota	Commercial		112.5	96.8	242.7
Early Ohio	Kittison Co. Farm Bureau, Hallock, Minn	Certified		126.0	87.0	275.5
Early Ohio	Market—Minnesota	Commercial		103.0	96.8	234.7
Early Ohio	William Newman, Alliance, Neb	Certified	205	153.0	.....	272.5
Early Ohio	Market—Minnesota	Commercial		112.5	116.0	238.0
	South Dakota Potato Growers Exchange, Watertown, South Dakota	Certified			127.0	.....
Irish Cobbler	Market—Minnesota	Commercial			148.0	.....
Irish Cobbler	South Dakota Potato Growers Exchange, Watertown, South Dakota	Certified			122.0	.....
Irish Cobbler (*c*)	Market—Minnesota	Certified	196	.....	.....	.....

(*a*) All seed treated before planting.
(*b*) This seed was bought on the market and used for checks.
(*c*) Seed became heated before planting.

The experiments thus far show that the production of certified seed has materially raised the standards of commercial seed stock. Each year a large number of potato growers write to potato growers in Kansas stating that although the seed they have for sale is not certified seed, it was grown from certified seed. It has been a common observation that a large amount of the commercial seed which has been coming to Kansas in the last three years looks better and has less dry rot than that imported during previous years **It should be remembered, however, that many growers make the mistake of judging the value or desirability of seed potatoes by their appearance alone. This is a serious mistake, for the reason that the yielding qualities are unknown. Two bushels of potatoes may look exactly alike in type, color, freedom from disease, i. e., in all general outward appearances; still one may outyield the other by 20 per cent.**

TABLE X.—Results of coöperative experiments with various strains of potato seed from various states, 1923 (*a*).

VARIETY	Source of seed	Yields per acre—bushels			
		Farm of A. W. Travis, Manhattan, Kan.	Farm of H. V. Cochran, Silver Lake, Kan.	Farm of Hulpieu & Fischer, Dodge City, Kan.	Farm of A. J. Parnell, Lawrence, Kan.
Irish Cobbler	Market (*b*)—Minn	144 (*d*)			211 (*d*)
Irish Cobbler	L. D. Sweet, Carbondale, Colo	175 (*c*)		144.0 (*c*)	239 (*c*)
Irish Cobbler	Market—Minn	190 (*d*)		138.3 (*c*)	227 (*d*)
Irish Cobbler	O. J. Wold, Ray, Minn	164 (*c*)		153.3 (*c*)	
Irish Cobbler	Market—Minn	174 (*d*)	306.9 (*c*)	87.3 (*c*)	200 (*d*)
Irish Cobbler	E. D. Askegaard, Moorehead, Minn	194 (*c*)	302.4 (*c*)	117.0 (*c*)	200 (*c*)
Irish Cobbler	Market—Minn	160 (*d*)	288.9 (*c*)	135.8 (*c*)	188 (*d*)
Irish Cobbler	J. A. Dixon, Argonne, Wis	179 (*c*)	321.3 (*c*)	152.5 (*c*)	
Irish Cobbler	Market—Minn	196 (*d*)		110.0 (*c*)	
Irish Cobbler	Home grown mulched		294.3 (*d*)		
Irish Cobbler	Home grown unmulched		165.3 (*d*)		
Irish Cobbler	Market—Minn			100.0 (*d*)	
Early Ohio	Market—Minn			104.3 (*c*)	
Early Ohio	Albert Weaver, Bird City, Kan	149 (*d*)		113.0 (*c*)	150 (*d*)
Early Ohio	Market—Minn	172 (*d*)	116.1 (*d*)	34.0 (*d*)	172 (*d*)
Early Ohio	Hulpieu & Fischer, Dodge City, Kan	154 (*d*)		89.5 (*c*)	166 (*d*)
Early Ohio	Market—Minn		205.2 (*d*)	55.0 (*d*)	
Early Ohio	Market—Minn			63.3 (*d*)	
Triumph	Market—Minn			84.6 (*c*)	
		30 (*d*)			

(*a*) The severe freezes that occurred in the spring undoubtedly influenced the yields in some of these tests. These data should be interperted with this in mind.
(*b*) "Market" has reference to commercial seed which was purchased on the market and used for checks in these tests.
(*c*) Certified seed.
(*d*) Commercial seed.

Table X summarizes the data on the study of various strains of seed potatoes from various states in 1923. The strains of Irish Cobbler grown were secured from growers recommended by the state inspectors as producing the best strains in their states. The results obtained would indicate:

1. That several states are growing seed adapted to Kansas conditions, this having been found to be the case in the tests during 1921 and 1922.
2. That some strains of seed are superior to the average run of seed.
3. That it would be desirable for Kansas growers to locate good strains of seed for their seed stock.

POTATOES UNDER IRRIGATION IN KANSAS.

Areas of land along the river valleys in western Kansas are well adapted to potato culture if water can be economically applied. Several growers in the Dodge City district have demonstrated that very satisfactory yields and a good quality of potatoes can be grown in this district. The chief problem seems to be the cost of the application of water. In many cases the cost is very small and the state irrigation engineer states that, "The Arkansas river valley lends itself ideally for the application of water at a small cost."

In 1922 some of the highest yields in the state were obtained in the irrigated district. The quality of these potatoes was excellent. This fact was brought out forcibly when the potatoes were marketed and were bought in preference to others on the market at the same time. In growing potatoes under irrigation in Kansas it is well to remember that this is still a new industry. Conditions are different in some respects from other potato sections and it is well to start in a small way until experience has been gained. At present the irrigated districts are troubled but little with plant diseases because the region is new. All potatoes should be treated before planting, not only to rid the tubers of the disease organisms, but also to keep the organisms from becoming established in the soil. Indications are that in the higher altitudes in western Kansas the conditions are more favorable for some of the diseases to live over in the soil than in eastern Kansas. Potatoes from the extreme western part of the state show Rhizoctonia sclerotia in abundance, a condition which is not found on the potatoes grown in the eastern part of the state. In view of these facts, every precaution should be taken to guard against the introduction and spread of diseases in the new districts.

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